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COMPARATIVE VERIFICATION OF GUIDANCE AND LOCAL
AVIATION/PUBLIC WEATHER FORECASTS--No. 15
(October 1982-March 1983)

Gary M. Carter, J. Paul Dallavalle,
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## 1. INTRODUCTION

This is the fifteenth in the series of Techniques Development Laboratory (TDL) office notes which compare the performance of TDL's automated guidance forecasts with National Weather Service (NWS) local forecasts made at Weather Service Forecast Offices (WSFO's). The local forecasts, which are produced subjectively, may or may not be based on the automated guidance. In this report, we present verification statistics for the cool season months of October 1982 through March 1983 for probability of precipitation (PoP), precipitation type (rain, freezing rain, or snow), surface wind, opaque sky cover (cloud amount), ceiling height, visibility, and maximum/minimum (max/min) temperature. The PoP, ceiling height, visibility, and max/min temperature verification results are provided for both forecast cycles, 0000 and 1200 GMT.

The objective guidance is based on equations developed through application of the Model Output Statistics (MOS) technique (Glahn and Lowry, 1972). Over the years we have derived many sets of prediction equations by using archived surface observations and forecast fields from the Limited-area Fine Mesh (LFM) model (Gerrity, 1977; Newell and Deaven, 1981; National Weather Service, 1981a), the Trajectory model (Reap, 1972), and/or the 6-layer coarse mesh Primitive Equation (PE) model (Shuman and Hovermale, 1968). Unless indicated otherwise, we usually refer to MOS forecasts based on the LFM model as "early" guidance; "final" guidance indicates the objective forecasts were based primarily on PE data. Also, the observation times of surface weather elements used as predictors in the early and final guidance generally differed. The final guidance is no longer disseminated operationally due to the superiority of the early guidance, but comparative results for previous years are included on the figures presented in this report.

The local public weather PoP forecasts used for this verification were official forecasts obtained from the Coded City Forecast (FPUS4) bulletin. In contrast, the local aviation forecasts from the WSFO's were collected by the Services Evaluation Branch of the Office of Meteorology for the purposes of the NWS combined aviation/public weather verification system (National Weather Service, 1973). These forecasts were recorded for verification according to the direction that they be "... not inconsistent with ..." the official weather prognosis. Surface observations as late as 2 hours before the first valid forecast time may have been used in the preparation of the local forecasts.

In the past, local max/min forecasts from the FPUS4 bulletin were compared with the MOS temperature guidance. However, the verification procedure was controversial because the local forecast was valid for a 12- or 18-h period, while the corresponding guidance applied to a particular calendar day. Hence,

cycle PoP forecasts. Due to the loss of local forecast data, we did not include the local verification results for the 1981-82 cool season. Fig. 2.1 indicates both local and guidance 0000 GMT first-period forecasts maintained about constant skill over the past 4 years, while there was a gradual decline in the skill of the third-period forecasts.

## 3. PRECIPITATION TYPE

The new objective conditional probability of precipitation type (PoPT) forecast system described in Technical Procedures Bulletin No. 319 (National Weather Service, 1982c) and Bocchieri and Maglaras (1983) provides categorical forecasts for three categories: frozen (snow or ice pellets), freezing (freezing rain or drizzle), and liquid (rain). Precipitation in the form of mixed snow and ice pellets is included in the frozen category; any mixed precipitation type (including freezing rain or drizzle) is included in the freezing category; all other mixed precipitation types are included in the liquid category. In this report, the frozen, freezing, and liquid categories will be referred to as snow, freezing rain, and rain, respectively.

For verification purposes, local categorical forecasts of precipitation type (made at about 1000 GMT) are recorded for three valid times: 1800 GMT (today), 0600 GMT (tonight), and 1800 GMT (tomorrow). Note, this is a conditional forecast; that is, it's a forecast of the type of precipitation if precipitation actually occurs. Therefore, a precipitation type forecast is always recorded. Similarly, the PoPT guidance forecasts are conditional and are available whether or not precipitation occurs.

Table 3.1 lists the 61 stations used for this verification study. Of course, the verification included only those cases in which precipitation actually occurred. Also, since we were concerned that some forecasters may not have put much effort into making the conditional forecasts when they considered precipitation to be unlikely, we used cases only when the local PoP was $\geq 30\%$. The PoP forecasts were valid for 12-h periods centered on the 18-, 30-, and 42-h projections from 0000 GMT.

We compared the PoPT guidance with local forecasts for the snow, freezing rain, and rain categories. Table 3.2 shows the verification results. The bias by category[1] values for freezing rain are not shown because there weren't enough cases to provide meaningful results. The percents correct and skill scores[2] for all stations combined indicate that the local and guidance forecasts were of comparable skill for the 18- and 30-h projections. For the

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[1] In the discussion of precipitation type, surface wind, opaque sky cover, ceiling height, and visibility, bias by category refers to the number of forecasts of a particular category (event) divided by the number of observations of that category. A value of 1.0 denotes unbiased forecasts for a particular category.

[2] The skill score used throughout this report is the Heidke skill score (Panofsky and Brier, 1965).

less than 8 knots, the wind forecasts were verified in two ways. First, for all those cases in which both the local and objective wind speed forecasts were at least 8 knots, the mean absolute error (MAE) of speed was computed. Cases where the observed wind was calm were then eliminated from this sample and the MAE of direction was computed. Second, for all cases where both local and automated forecasts were available, skill score, percent correct, and bias by category were computed from contingency tables of wind speed. The seven categories in the tables were: <8, 8-12, 13-17, 18-22, 23-27, 28-32, and >32 knots. Table 4.1 lists the 90 stations used in the verification. All the objective forecasts of wind speed were adjusted by an "inflation" technique (Klein et al., 1959) involving the multiple correlation coefficient and the mean value of wind speed for each particular station and forecast valid time.

The results for all 90 stations combined are shown in Tables 4.2 and 4.3. In Table 4.2, the forecast direction MAE's reveal an advantage for the guidance that is 2° for the 18-h projection and 4° for both the 30- and 42-h projections. The speed MAE's, skill scores, and percents correct also are generally better for the guidance. The bias by category values in Table 4.2 and the contingency tables in Table 4.3, indicate the guidance overestimated winds stronger than 22 knots (i.e., categories 5, 6, and 7) for all three forecast projections, whereas the local forecasts underestimated speeds in these categories. We have noticed this characteristic of the guidance since the 1981-82 cool season. We think it is partly due to the implementation of new equations. Some of the overforecasting may also be related to LFM model errors in forecasting the movement and intensity of synoptic scale weather systems. Although the guidance was not developed to overforecast strong winds, this characteristic may actually be desirable.

Tables 4.4-4.7 show scores for the NWS Eastern, Southern, Central, and Western Regions, respectively. The regional comparisons generally have the same characteristics as for the entire group of stations, except the advantage of the guidance over the local forecasts varies from region to region. However, for all areas except the Eastern Region, the local speed MAE's were generally as good as, or better than, those for the guidance.

Table 4.8 shows the distribution of wind direction absolute errors by categories--0-30°, 40-60°, 70-90°, 100-120°, 130-150°, and 160-180°-- for all 90 stations combined. The guidance had about 4%, 7%, and 5% fewer errors of 40° or more than did the local forecasts for the 18-, 30-, and 42-h projections, respectively.

The distribution of direction errors for each of the four regions are given in Tables 4.9-4.12. In general, these results are much like those in Table 4.8 except, once again, the advantage of the guidance over the local forecast differs in magnitude from region to region.

A comparison of overall MAE's and skill scores during the past 10 cool seasons for the 18- and 42-h guidance and local forecasts is presented in Figs. 4.1-4.4. The verification data throughout this period were relatively homogeneous; the number of stations varied only slightly from season to season, while the basic set of verification stations remained the same. The MAE's and skill scores in these figures reveal the consistent superiority of the early over the final guidance during the period when both were available.

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local and objective categorical predictions. Using these tables, we computed the percent correct, skill score, and bias by category.

The results for all stations combined are shown in Table 5.2. For all three projections, the guidance forecasts were superior to the local forecasts in terms of percent correct and skill score. Examination of the bias by category scores shows the guidance forecasts were better (i.e., closer to 1.0) than the locals for each projection and category. The local forecasts exhibited a tendency to underforecast the clear and overcast categories, and overforecast the scattered and broken categories.

The verification scores for stations in the NWS Eastern, Southern, Central, and Western Regions are given in Tables 5.3-5.6, respectively. In the regional breakdown, except for the 18-h forecasts for the Western Region, the percents correct, skill scores, and bias by category values for the guidance forecasts were generally better than those for the local forecasts.

Percents correct and skill scores for the past nine cool seasons are shown in Figs. 5.1 and 5.2, respectively, for the 18- and 42-h projections. The figures show that for 1982-83 both guidance and local forecasts improved over those for the previous year.

Figs. 5.3-5.6 show bias values for categories 1 through 4, respectively, for the 18-h forecasts.[3] The local forecast biases for all four categories, with some minor fluctuations, have remained relatively constant over the years. The graphs also show that the locals tend to underforecast the clear and overcast categories, and overforecast the scattered and broken categories. Over the years, the biases for the guidance have been superior to those for the local forecasts.

## 6. CEILING AND VISIBILITY

During the 1982-83 cool season, the ceiling and visibility guidance was produced by the prediction equations described in Technical Procedures Bulletin No. 303 (National Weather Service, 1981b). Operationally, the guidance was based primarily on LFM model output and 0300 (1500) GMT surface observations.

Verification scores were computed for both local and guidance forecasts for the 90 stations listed in Table 4.1. Persistence based on an observation taken at 0900 GMT for the 0000 GMT forecast cycle and at 2100 (or 2200) GMT for the 1200 GMT forecast cycle was used as a standard of comparison. The objective forecasts were verified for both cycles for the 12-, 18-, 24-, 36-, and 48-h projections. The local forecasts were verified for the 12-, 15-, and 21-h projections from 0000 and 1200 GMT. On a daily basis, the guidance

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[3]In many of our past verification reports (e.g., Schwartz et al., 1981), the bias by category graphs were plotted on a linear scale. Here, the bias graphs are plotted on a semi-log scale. The reason for the change is because we think that biases of X and 1/X are equally bad. For example, forecasting an event four times as often as it occurred should appear as bad as forecasting that event only one-fourth as many times as it occurred.

remained about the same over the years, while skill scores for the 18-h forecasts have been variable. In particular, the 1982-83 ceiling and visibility guidance for the 18-h projection decreased in skill. Figs. 6.5-6.8 indicate the ceiling and visibility guidance overforecast categories 1 and 2. This appears to be the result of the new prediction equations and threshold values which were implemented during the 1981-82 cool season.

## 7. MAXIMUM/MINUMUM TEMPERATURE

The objective max/min temperature guidance for October 1982 through March 1983 was generated by the LFM-based regression equations described in Technical Procedures Bulletin No. 285 (National Weather Service, 1980a). The predictand data for these equations consisted of local calendar day max or min temperatures valid approximately 24, 36, 48, and 60 hours after the model initial data times of 0000 and 1200 GMT. The guidance was based on equations developed by stratifying archived LFM model forecasts, station observations, and the first two harmonics of the day of the year into seasons of 3-mo duration (Dallavalle et al., 1980). We defined fall as September-November, winter as December-February, and spring as March-May. Station observations taken 3 hours after initial model time were also included as predictors in many of the equations for the first two periods.

Since the automated max/min forecasts are valid for the local calendar day, the first period objective forecast of the max based on 0000 GMT model data is for the calendar day starting at the subsequent midnight. The max/min guidance for the other periods corresponds to specific calendar days in an analogous manner.

In prior verification reports (e.g., Schwartz et al., 1981), we compared the skill of the local max/min temperature forecasts with that of the objective guidance. However, the valid period of the local forecasts corresponds to a daytime max and a nighttime min, rather than a particular calendar day. This procedure of using a calendar day verifying observation generated a considerable amount of controversy. Because appropriate daytime max and nighttime min observations are not available for verification, the 1982 NWS Line Forecasters Technical Advisory Committee recommended that comparisons between local and objective max/min forecasts no longer be published. In this report, we have complied with this request; only the automated forecasts were verified and discussed. Eventually, with implementation of the new AFOS verification system, the required observations will be available and comparisons between the guidance and locals will be possible.

For the 1982-83 cool season, we verified both the 0000 and 1200 GMT cycle objective forecasts. Because a matched sample between the local forecasts and automated guidance was not required, the number of cases increased by approximately 55% from the previous cool season. Since the max/min verification statistics generally are based on stable samples, this relatively large change in the number of cases should not alter significantly the overall measures of accuracy. For the 1982-83 cool season, the mean algebraic error (forecast minus observed temperature), mean absolute error, and the number of absolute errors $\geq 10°F$ were computed for 87 stations (Table 2.1). For the 0000 GMT cycle, forecast projections of approximately 24 (max), 36 (min), 48 (max), and 60 (min) hours were verified; for the 1200 GMT cycle, forecasts

were not plotted for the 1981-82 and 1982-83 cool seasons. It is evident that the max temperature forecasts have improved considerably over the period of record. From the 1971-72 to the 1982-83 cool season, the guidance improved by 1.5°F and 1.3°F at the 24- and 48-h projections, respectively. In fact, the smallest errors yet recorded were seen in the 1982-83 cool season. Note that a large improvement occurred in the guidance during the 1973-74 cool season when MOS equations were first used (Klein and Hammons, 1975). Improvements in the early guidance coincided with the introduction of LFM-based equations prior to the 1978-79 cool season (Carter et al., 1979) and with the use of 3-mo LFM equations during the 1980-81 cool season (Dallavalle et al., 1980).

An analogous time series is shown in Fig. 7.2 for the min forecasts from 0000 GMT. Again, no results are available for the local forecasts for the 1981-82 and 1982-83 cool seasons. Also, verifications for the 60-h projection are shown only for the last six cool seasons. Natural variability and the difficulty of predicting the min during the cool season result in highly irregular error curves. Nevertheless, there has been an overall improvement in the min forecasts during the period of record. The greatest improvement in the 36-h guidance coincided with the introduction of 3-mo PE-based equations prior to the 1975-76 cool season (Hammons et al., 1976). Analogously, the 60-h guidance improved with the use of 3-mo LFM-based equations during the 1980-81 cool season (Dallavalle et al., 1980). Ironically, while the max temperature forecasts were very accurate during the 1982-83 cool season, some of the largest errors in the min guidance over the last four seasons occurred during 1982-83. We've already mentioned that the winter was abnormally warm. Also, numerous changes have been made to the LFM model over the past few years (e.g., National Weather Service, 1981a). These changes may have modified some of the systematic biases in the model. Furthermore, if the changes had a strong effect on the moisture fields, then the MOS minimum temperature equations, which frequently use the mean relative humidity or precipitable water as predictors, would especially be affected.

## 8. SUMMARY

Highlights of the 1982-83 cool season verification results, summarized by general type of weather element are:

o Probability of Precipitation - The comparative verification involved 87 stations and forecast projections of 12-24, 24-36, and 36-48 hours from both 0000 and 1200 GMT. The NWS Brier scores for all stations combined for 0000 GMT indicate the local forecasts for all three periods were better than the corresponding LFM-based guidance. For 1200 GMT, the local forecasts were as good as, or better than, the guidance for all three periods. Improvements of locals over guidance ranged from 5.6% for the first period 0000 GMT cycle to 0.1% for the third period 1200 GMT cycle. Although we do not have scores for the local forecasts for 1981-82 due to loss of data, it appears both local and guidance 0000 GMT first-period forecasts maintained about constant skill over the past 4 years, while there was a gradual decline in the skill of the third-period forecasts over that period.

after the initial model time. We found that the min temperature guidance had a pronounced cold bias (negative algebraic error) in all NWS regions and for all projections. The biases for the max guidance tended to be smaller than for the min. Moreover, the mean absolute errors for all stations combined indicated the min temperature was more difficult to predict than the max for the same projection. The max guidance during the 1982-83 cool season was the most accurate yet, while the min forecasts were the least accurate since the 1979-80 cool season. This latest cool season was extraordinary because the 1982-83 winter ranked as the fifth warmest over the entire United States since 1931. It appears that the MOS forecast equations, which were developed from a series of relatively cold winters in the mid and late 1970's, were unable to account for last winter's warmer than normal conditions.

## 9. ACKNOWLEDGEMENTS

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Table 2.2  Comparative verification of early guidance and local PoP forecasts
for 87 stations, 0000 GMT cycle.

| Projection (h) | Type of Forecast | Brier Score | Improvement Over Guidance (%) | Improvement Over Climate (%) | Number of Cases |
|---|---|---|---|---|---|
| 12-24 (1st period) | Early | .0942 | | 47.1 | |
| | Local | .0890 | 5.6 | 50.0 | 11020 |
| 24-36 (2nd period) | Early | .1128 | | 34.7 | |
| | Local | .1117 | 1.1 | 35.4 | 11024 |
| 36-48 (3rd period) | Early | .1243 | | 29.6 | |
| | Local | .1210 | 2.6 | 31.5 | 10936 |

Table 2.5.  Same as Table 2.2 except for 23 stations in the Central Region.

| Projection (h) | Type of Forecast | Brier Score | Improvement Over Guidance (%) | Improvement Over Climate (%) | Number of Cases |
|---|---|---|---|---|---|
| 12-24 (1st period) | Early | .0875 | | 43.7 | |
| | Local | .0842 | 3.7 | 45.8 | 3077 |
| 24-36 (2nd period) | Early | .1165 | | 32.0 | |
| | Local | .1160 | 0.5 | 32.3 | 3075 |
| 36-48 (3rd period) | Early | .1202 | | 23.8 | |
| | Local | .1182 | 1.6 | 25.1 | 3055 |

Table 2.6.  Same as Table 2.2 except for 15 stations in the Western Region.

| Projection (h) | Type of Forecast | Brier Score | Improvement Over Guidance (%) | Improvement Over Climate (%) | Number of Cases |
|---|---|---|---|---|---|
| 12-24 (1st period) | Early | .1129 | | 35.7 | |
| | Local | .1024 | 9.3 | 41.7 | 2017 |
| 24-36 (2nd period) | Early | .1252 | | 26.7 | |
| | Local | .1180 | 5.7 | 30.9 | 2018 |
| 36-48 (3rd period) | Early | .1419 | | 19.8 | |
| | Local | .1346 | 5.1 | 23.9 | 2002 |

Table 2.8.  Same as Table 2.7 except for 25 stations in the Eastern Region.

| Projection (h) | Type of Forecast | Brier Score | Improvement Over Guidance (%) | Improvement Over Climate (%) | Number of Cases |
|---|---|---|---|---|---|
| 12-24 (1st period) | Early | .0946 | | 52.2 | |
| | Local | .0958 | -1.3 | 51.6 | 2348 |
| 24-36 (2nd period) | Early | .1140 | | 43.5 | |
| | Local | .1180 | -3.4 | 41.5 | 2347 |
| 36-48 (3rd period) | Early | .1233 | | 37.9 | |
| | Local | .1275 | -3.4 | 35.8 | 2348 |

Table 2.9.  Same as Table 2.7 except for 24 stations in the Southern Region.

| Projection (h) | Type of Forecast | Brier Score | Improvement Over Guidance (%) | Improvement Over Climate (%) | Number of Cases |
|---|---|---|---|---|---|
| 12-24 (1st period) | Early | .0969 | | 37.0 | |
| | Local | .0926 | 4.4 | 39.8 | 2913 |
| 24-36 (2nd period) | Early | .1005 | | 43.7 | |
| | Local | .0978 | 2.6 | 45.1 | 2907 |
| 36-48 (3rd period) | Early | .1130 | | 26.6 | |
| | Local | .1122 | 0.7 | 27.2 | 2914 |

Table 3.1. Sixty-one stations used for comparative verification of guidance and local precipitation type forecasts.

| | | | |
|---|---|---|---|
| DCA | Washington, D.C. | DFW | Dallas-Ft. Worth, Texas |
| PWM | Portland, Maine | IAH | Houston, Texas |
| BOS | Boston, Massachusetts | SAT | San Antonio, Texas |
| ALB | Albany, New York | DEN | Denver, Colorado |
| BUF | Buffalo, New York | ORD | Chicago (O'Hare), Illinois |
| JFK | New York (Kennedy), New York | IND | Indianapolis, Indiana |
| SYR | Syracuse, New York | DSM | Des Moines, Iowa |
| CLT | Charlotte, North Carolina | TOP | Topeka, Kansas |
| RDU | Raleigh-Durham, North Carolina | DTW | Detroit, Michigan |
| CLE | Cleveland, Ohio | SDF | Louisville, Kentucky |
| CMH | Columbus, Ohio | MSP | Minneapolis, Minnesota |
| PHL | Philadelphia, Pennsylvania | MCI | Kansas City, Missouri |
| PIT | Pittsburgh, Pennsylvania | STL | St. Louis, Missouri |
| PVD | Providence, Rhode Island | OMA | Omaha, Nebraska |
| CHS | Charleston, South Carolina | BIS | Bismarck, North Dakota |
| CAE | Columbia, South Carolina | FAR | Fargo, North Dakota |
| ORF | Norfolk, Virginia | FSD | Sioux Falls, South Dakota |
| CRW | Charleston, West Virginia | RAP | Rapid City, South Dakota |
| BHM | Birmingham, Alabama | MKE | Milwaukee, Wisconsin |
| LIT | Little Rock, Arkansas | CYS | Cheyenne, Wyoming |
| JAX | Jacksonville, Florida | PHX | Phoenix, Arizona |
| MIA | Miami, Florida | LAX | Los Angeles, California |
| ATL | Atlanta, Georgia | SAN | San Diego, California |
| MSY | New Orleans, Louisiana | SFO | San Francisco, California |
| SHV | Shreveport, Louisiana | BOI | Boise, Idaho |
| JAN | Jackson, Mississippi | GTF | Great Falls, Montana |
| ABQ | Albuquerque, New Mexico | RNO | Reno, Nevada |
| OKC | Oklahoma City, Oklahoma | PDX | Portland, Oregon |
| TUL | Tulsa, Oklahoma | SLC | Salt Lake City, Utah |
| MEM | Memphis, Tennessee | GEG | Spokane, Washington |
| | | SEA | Seattle-Tacoma, Washington |

Table 3.3. Comparative verification of early PoPT guidance and local
forecasts for 61 stations, 0000 GMT cycle. Only those cases in which the
locals and guidance differed, and the local PoP was >30%, are included.

| Projection (h) | Type of Forecast | Percent Correct | Number of Cases |
|---|---|---|---|
| 18 | Early | 46.7 | |
| | Local | 51.7 | 60 |
| 30 | Early | 44.8 | |
| | Local | 44.8 | 67 |
| 42 | Early | 49.2 | |
| | Local | 44.6 | 65 |

Table 4.2. Comparative verification of early guidance and local surface wind forecasts for 90 stations, 0000 GMT cycle.

| Fcst. Proj. (h) | Type of Fcst. | Direction Mean Abs. Error (Deg) | Direction No. of Cases | Speed Mean Abs. Error (Kts) | Mean Fcst. (Kts) | Mean Obs. (Kts) | Speed No. of Cases | Skill Score | Percent Fcst. Correct | Contingency Table — Bias by Category 1 (No. Obs) | 2 (No. Obs) | 3 (No. Obs) | 4 (No. Obs) | 5 (No. Obs) | 6 (No. Obs) | 7 (No. Obs) | No. of Cases |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | Early | 27 | 7464 | 3.3 | 12.9 | 12.0 | 7523 | .327 | 54.0 | 1.03 | 0.97 | 0.97 | 1.02 | 1.37 | 1.30 | 1.80 | 13681 |
|    | Local | 29 |      | 3.4 | 13.2 |      |      | .283 | 50.6 | 0.76 (5196) | 1.16 (5067) | 1.18 (2505) | 1.05 (730) | 0.68 (136) | 0.68 (37) | 0.70 (10) | |
| 30 | Early | 31 | 4499 | 3.8 | 12.2 | 10.6 | 4576 | .324 | 61.8 | 1.01 | 0.99 | 1.00 | 1.01 | 1.10 | 0.82 | 1.60 | 13550 |
|    | Local | 35 |      | 4.0 | 12.4 |      |      | .278 | 57.7 | 0.89 (7949) | 1.20 (3815) | 1.11 (1353) | 0.95 (351) | 0.67 (60) | 0.59 (17) | 0.20 (5) | |
| 42 | Early | 36 | 7215 | 4.0 | 13.1 | 11.6 | 7287 | .232 | 47.3 | 0.99 | 0.98 | 1.00 | 1.09 | 1.51 | 1.62 | 2.78 | 13567 |
|    | Local | 40 |      | 3.9 | 12.8 |      |      | .199 | 45.6 | 0.82 (5149) | 1.20 (5041) | 1.04 (2475) | 0.82 (722) | 0.64 (134) | 0.46 (37) | 0.44 ( 9) | |

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Table 4.4. Same as Table 4.2 except for 23 stations in the Eastern Region.

| Fcst. Proj. (h) | Type of Fcst. | Direction Mean Abs. Error (Deg) | Direction No. of Cases | Speed Mean Abs. Error (Kts) | Mean Fcst. (Kts) | Mean Obs. (Kts) | No. of Cases | Skill Score | Percent Fcst. Correct | Contingency Table — Bias by Category 1 (No. Obs) | 2 (No. Obs) | 3 (No. Obs) | 4 (No. Obs) | 5 (No. Obs) | 6 (No. Obs) | 7 (No. Obs) | No. of Cases |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | Early | 26 | 2228 | 2.9 | 12.5 | 11.9 | 2245 | .338 | 54.8 | 1.07 | 0.97 | 0.94 | 0.99 | 1.24 | 0.60 | 0.00 | 3823 |
|  | Local | 28 |  | 3.3 | 13.3 |  |  | .262 | 49.2 | 0.70 (1313) | 1.14 (1511) | 1.21 (763) | 1.14 (200) | 0.79 (29) | 1.00 (5) | 0.50 (2) |  |
| 30 | Early | 28 | 1286 | 3.6 | 11.9 | 11.0 | 1308 | .351 | 63.8 | 1.05 | 0.98 | 0.81 | 0.87 | 1.27 | 0.50 | 1.00 | 3816 |
|  | Local | 33 |  | 3.9 | 12.9 |  |  | .312 | 58.4 | 0.84 (2229) | 1.28 (1026) | 1.14 (441) | 1.03 (104) | 1.64 (11) | 1.00 (4) | 0.00 (1) |  |
| 42 | Early | 32 | 2204 | 3.4 | 12.6 | 11.7 | 2223 | .264 | 49.7 | 1.01 | 0.99 | 0.95 | 1.05 | 1.68 | 1.00 | 0.50 | 3795 |
|  | Local | 37 |  | 3.6 | 12.8 |  |  | .205 | 46.1 | 0.75 (1300) | 1.21 (1503) | 1.05 (758) | 0.85 (199) | 0.79 (28) | 0.80 (5) | 0.00 (2) |  |

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Table 4.6. Same as Table 4.2 except for 28 stations in the Central Region.

| Fcst. Proj. (h) | Type of Fcst. | Direction | | Speed | | | | | | Contingency Table | | | | | | | No. of Cases |
| | | Mean Abs. Error (Deg) | No. of Cases | Mean Abs. Error (Kts) | Mean Fcst. (Kts) | Mean Obs. (Kts) | No. of Cases | Skill Score | Percent Fcst. Correct | Bias by Category | | | | | | | |
| | | | | | | | | | | 1 (No. Obs) | 2 (No. Obs) | 3 (No. Obs) | 4 (No. Obs) | 5 (No. Obs) | 6 (No. Obs) | 7 (No. Obs) | |
| 18 | Early | 24 | 2482 | 3.2 | 13.3 | 12.5 | 2496 | .322 | 52.4 | 1.12 | 0.91 | 0.96 | 0.94 | 1.34 | 1.28 | 1.86 | 4191 |
| | Local | 26 | | 3.4 | 13.5 | | | .274 | 49.2 | 0.82 (1333) | 1.05 (1636) | 1.20 (878) | 1.01 (251) | 0.82 (61) | 0.72 (25) | 0.86 (7) | |
| 30 | Early | 28 | 1617 | 3.8 | 12.6 | 11.1 | 1634 | .315 | 58.2 | 1.05 | 0.92 | 0.95 | 1.07 | 1.18 | 1.11 | 2.33 | 4196 |
| | Local | 31 | | 3.8 | 12.4 | | | .259 | 54.3 | 0.96 (2159) | 1.07 (1366) | 1.03 (486) | 0.96 (140) | 0.36 (33) | 0.67 (9) | 0.33 (3) | |
| 42 | Early | 35 | 2487 | 4.0 | 13.6 | 12.0 | 2501 | .222 | 45.2 | 1.05 | 0.93 | 0.96 | 1.09 | 1.64 | 1.42 | 2.83 | 4156 |
| | Local | 39 | | 4.0 | 13.1 | | | .171 | 42.7 | 0.83 (1321) | 1.14 (1629) | 1.03 (870) | 0.94 (247) | 0.85 (59) | 0.46 (24) | 0.67 (6) | |

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Table 4.8. Distribution of absolute errors associated with early guidance and local forecasts of surface wind direction for 90 stations, 0000 GMT cycle.

| Forecast Projection (h) | Type of Forecast | Percentage Frequency of Absolute Errors by Category | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0-30° | 40-60° | 70-90° | 100-120° | 130-150° | 160-180° |
| 18 | Early | 76.0 | 15.3 | 4.5 | 2.0 | 1.3 | 1.0 |
| | Local | 72.1 | 17.6 | 5.1 | 2.4 | 1.7 | 1.1 |
| 30 | Early | 71.4 | 16.2 | 6.0 | 3.0 | 1.9 | 1.4 |
| | Local | 64.7 | 19.8 | 7.5 | 3.8 | 2.6 | 1.6 |
| 42 | Early | 64.3 | 19.6 | 7.5 | 4.0 | 2.7 | 1.9 |
| | Local | 59.6 | 21.3 | 8.3 | 4.9 | 3.5 | 2.4 |

Table 4.11.  Same as Table 4.8 except for 28 stations in the Central Region.

| Forecast Projection (h) | Type of Forecast | Percentage Frequency of Absolute Errors By Category | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0-30° | 40-60° | 70-90° | 100-120° | 130-150° | 160-180° |
| 18 | Early | 81.7 | 11.3 | 3.5 | 1.7 | 1.2 | 0.6 |
| | Local | 77.0 | 14.5 | 4.2 | 2.1 | 1.4 | 0.8 |
| 30 | Early | 75.1 | 15.6 | 4.2 | 2.2 | 1.4 | 1.5 |
| | Local | 69.8 | 17.7 | 6.4 | 2.9 | 1.7 | 1.5 |
| 42 | Early | 66.6 | 18.1 | 6.3 | 4.0 | 3.3 | 1.7 |
| | Local | 61.9 | 20.3 | 7.2 | 4.8 | 3.7 | 2.1 |

Table 4.12.  Same as Table 4.8 except for 17 stations in the Western Region.

| Forecast Projection (h) | Type of Forecast | Percentage Frequency of Absolute Errors By Category | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0-30° | 40-60° | 70-90° | 100-120° | 130-150° | 160-180° |
| 18 | Early | 61.4 | 17.5 | 8.1 | 4.5 | 4.4 | 4.0 |
| | Local | 60.0 | 18.5 | 7.3 | 5.4 | 4.6 | 4.1 |
| 30 | Early | 59.2 | 17.5 | 10.3 | 5.4 | 4.4 | 3.2 |
| | Local | 53.5 | 20.7 | 10.5 | 5.2 | 5.4 | 4.7 |
| 42 | Early | 53.5 | 19.3 | 11.6 | 6.0 | 4.5 | 5.2 |
| | Local | 49.0 | 18.2 | 10.5 | 8.6 | 6.9 | 6.8 |

Table 5.2. Comparative verification of early guidance and local forecasts of four
categories of opaque sky cover (clear, scattered, broken, and overcast) for
90 stations, 0000 GMT cycle.

| Projection (h) | Type of Forecast | Bias by Category | | | | Percent Correct | Skill Score | Number of Cases |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | | | |
| 18 | Early | 1.12 | 0.76 | 1.09 | 1.00 | 54.0 | .372 | |
| | Local | 0.64 | 1.41 | 1.37 | 0.82 | 51.6 | .354 | 13664 |
| | No. Obs. | 3469 | 2724 | 2632 | 4839 | | | |
| 30 | Early | 1.18 | 0.74 | 0.95 | 0.94 | 57.0 | .369 | |
| | Local | 0.64 | 2.04 | 1.83 | 0.72 | 46.9 | .289 | 13349 |
| | No. Obs. | 4718 | 1824 | 1582 | 5225 | | | |
| 42 | Early | 1.30 | 0.72 | 0.93 | 0.99 | 48.7 | .296 | |
| | Local | 0.54 | 1.81 | 1.44 | 0.64 | 40.6 | .219 | 13586 |
| | No. Obs. | 3420 | 2696 | 2625 | 4845 | | | |

Table 5.5. Same as Table 5.2 except for 28 stations in the Central Region.

| Projection (h) | Type of Forecast | Bias by Category | | | | Percent Correct | Skill Score | Number of Cases |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | | | |
| 18 | Early | 1.24 | 0.77 | 1.10 | 0.93 | 53.2 | .360 | |
| | Local | 0.52 | 1.39 | 1.38 | 0.89 | 51.9 | .349 | 4183 |
| | No. Obs. | 950 | 875 | 784 | 1574 | | | |
| 30 | Early | 1.38 | 0.73 | 0.90 | 0.83 | 56.0 | .354 | |
| | Local | 0.56 | 2.17 | 2.03 | 0.68 | 44.7 | .263 | 4009 |
| | No. Obs. | 1274 | 557 | 453 | 1725 | | | |
| 42 | Early | 1.56 | 0.75 | 0.75 | 0.93 | 47.5 | .279 | |
| | Local | 0.37 | 1.81 | 1.59 | 0.64 | 38.8 | .190 | 4163 |
| | No. Obs. | 941 | 859 | 781 | 1582 | | | |

Table 5.6. Same as Table 5.2 except for 17 stations in the Western Region.

| Projection (h) | Type of Forecast | Bias by Category | | | | Percent Correct | Skill Score | Number of Cases |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | | | |
| 18 | Early | 1.05 | 0.79 | 1.07 | 1.04 | 51.0 | .335 | |
| | Local | 0.80 | 1.18 | 1.20 | 0.92 | 51.7 | .353 | 2312 |
| | No. Obs. | 626 | 431 | 520 | 735 | | | |
| 30 | Early | 1.11 | 0.74 | 1.17 | 0.94 | 51.8 | .324 | |
| | Local | 0.65 | 1.57 | 1.75 | 0.75 | 45.0 | .271 | 2310 |
| | No. Obs. | 806 | 389 | 341 | 774 | | | |
| 42 | Early | 1.16 | 0.74 | 0.99 | 1.03 | 46.4 | .273 | |
| | Local | 0.70 | 1.59 | 1.31 | 0.67 | 40.5 | .215 | 2298 |
| | No. Obs. | 616 | 438 | 518 | 726 | | | |

Table 6.2. Comparative verification of early guidance, persistence, and local ceiling height forecasts for 90 stations, 0000 GMT cycle.

| Projection (h) | Type of Forecast | Bias by Category | | | | | | Percent Correct | Skill Score |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | | |
| 12 | Early | 1.19 | 1.21 | 0.86 | 0.94 | 1.04 | 1.00 | 60.4 | .378 |
| | Local | 0.59 | 1.05 | 0.90 | 1.12 | 1.08 | 0.97 | 72.0 | .563 |
| | Persistence | 0.85 | 0.89 | 0.94 | 0.95 | 1.01 | 1.03 | 74.9 | .599 |
| | No. Obs. | 308 | 621 | 928 | 2099 | 2043 | 7557 | | |
| 15 | Local | 0.39 | 0.67 | 0.74 | 1.21 | 1.21 | 0.97 | 65.5 | .456 |
| | Persistence | 1.23 | 0.85 | 0.85 | 0.91 | 1.09 | 1.03 | 65.3 | .444 |
| | No. Obs. | 212 | 648 | 1024 | 2184 | 1894 | 7602 | | |
| 18 | Early | 0.88 | 1.18 | 0.84 | 0.97 | 1.09 | 1.00 | 62.7 | .385 |
| | Persistence | 3.78 | 1.28 | 0.99 | 0.81 | 1.12 | 0.99 | 60.7 | .357 |
| | No. Obs. | 69 | 429 | 880 | 2463 | 1853 | 7880 | | |
| 21 | Local | 0.25 | 0.35 | 0.70 | 1.22 | 1.18 | 0.95 | 64.9 | .400 |
| | Persistence | 5.00 | 1.66 | 1.25 | 0.92 | 1.00 | 0.95 | 57.8 | .294 |
| | No. Obs. | 52 | 331 | 694 | 2151 | 2069 | 8262 | | |
| 24 | Early | 1.24 | 1.32 | 0.87 | 0.92 | 0.93 | 1.03 | 64.9 | .367 |
| | Persistence | 3.84 | 1.63 | 1.36 | 1.05 | 0.95 | 0.93 | 55.4 | .247 |
| | No. Obs. | 68 | 337 | 641 | 1888 | 2191 | 8456 | | |
| 36 | Early | 1.81 | 1.68 | 0.75 | 0.90 | 0.78 | 1.03 | 55.3 | .295 |
| | Persistence | 0.84 | 0.88 | 0.93 | 0.95 | 1.02 | 1.04 | 46.3 | .143 |
| | No. Obs. | 309 | 624 | 940 | 2103 | 2038 | 7562 | | |
| 48 | Early | 1.41 | 1.34 | 0.94 | 0.94 | 0.85 | 1.04 | 60.1 | .284 |
| | Persistence | 3.84 | 1.61 | 1.35 | 1.05 | 0.94 | 0.93 | 45.7 | .086 |
| | No. Obs. | 68 | 341 | 644 | 1885 | 2204 | 8357 | | |

Table 6.4.  Same as Table 6.2 except for ceiling height, 1200 GMT cycle.

| Projection (h) | Type of Forecast | Bias by Category | | | | | | Percent Correct | Skill Score |
| | | 1 | 2 | 3 | 4 | 5 | 6 | | |
|---|---|---|---|---|---|---|---|---|---|
| 12 | Early | 1.44 | 1.38 | 0.95 | 0.95 | 0.98 | 1.00 | 67.2 | .416 |
| | Local | 0.47 | 0.80 | 0.86 | 1.30 | 0.98 | 0.96 | 76.1 | .582 |
| | Persistence | 0.81 | 0.94 | 1.03 | 1.13 | 0.94 | 0.99 | 77.0 | .593 |
| | No. Obs. | 64 | 334 | 636 | 1844 | 2162 | 8441 | | |
| 15 | Local | 0.34 | 0.84 | 0.84 | 1.38 | 0.86 | 0.98 | 70.4 | .483 |
| | Persistence | 0.47 | 0.86 | 0.92 | 1.15 | 0.97 | 0.99 | 68.5 | .445 |
| | No. Obs. | 110 | 368 | 714 | 1837 | 2145 | 8472 | | |
| 18 | Early | 1.22 | 1.60 | 0.70 | 0.94 | 0.93 | 1.02 | 63.4 | .376 |
| | Persistence | 0.31 | 0.68 | 0.82 | 1.15 | 0.97 | 1.03 | 63.2 | .368 |
| | No. Obs. | 170 | 460 | 793 | 1818 | 2091 | 7996 | | |
| 21 | Local | 0.28 | 0.95 | 0.95 | 1.39 | 0.83 | 0.98 | 62.0 | .382 |
| | Persistence | 0.21 | 0.57 | 0.74 | 1.09 | 1.00 | 1.06 | 58.4 | .298 |
| | No. Obs. | 252 | 550 | 871 | 1927 | 2050 | 7814 | | |
| 24 | Early | 1.31 | 1.64 | 0.77 | 0.87 | 0.91 | 1.02 | 58.6 | .343 |
| | Persistence | 0.18 | 0.51 | 0.71 | 1.02 | 1.02 | 1.10 | 54.8 | .251 |
| | No. Obs. | 295 | 612 | 915 | 2055 | 1996 | 7481 | | |
| 36 | Early | 1.24 | 1.44 | 0.93 | 0.91 | 0.88 | 1.04 | 62.4 | .319 |
| | Persistence | 0.78 | 0.93 | 1.02 | 1.12 | 0.95 | 0.99 | 52.5 | .160 |
| | No. Obs. | 67 | 342 | 641 | 1867 | 2150 | 8436 | | |
| 48 | Early | 1.42 | 1.64 | 0.76 | 0.97 | 0.77 | 1.03 | 54.0 | .272 |
| | Persistence | 0.17 | 0.51 | 0.69 | 1.02 | 1.01 | 1.11 | 44.6 | .086 |
| | No. Obs. | 305 | 621 | 931 | 2057 | 2004 | 7435 | | |

Table 6.6. Comparative verification for early guidance, persistence, and local ceiling height forecasts for 90 stations, 0000 GMT cycle. Scores are computed from two-category (categories 1 and 2 combined versus categories 3-6 combined) contingency tables.

| Projection (h) | Type of Forecast | Rel. Freq. Cats. 1&2 combined | Bias Cats. 1&2 combined | Percent Correct | Skill Score | Threat Score |
|---|---|---|---|---|---|---|
| 12 | Early | 0.069 | 1.21 | 90.7 | .339 | .241 |
|    | Local |       | 0.89 | 94.7 | .563 | .419 |
|    | Persistence | | 0.87 | 95.2 | .605 | .460 |
| 15 | Local | 0.063 | 0.60 | 93.7 | .343 | .230 |
|    | Persistence | | 0.94 | 93.5 | .442 | .313 |
| 18 | Early | 0.037 | 1.14 | 94.2 | .225 | .147 |
|    | Persistence | | 1.63 | 93.4 | .281 | .186 |
| 21 | Local | 0.028 | 0.34 | 96.9 | .164 | .096 |
|    | Persistence | | 2.11 | 93.3 | .203 | .132 |
| 24 | Early | 0.030 | 1.31 | 94.8 | .220 | .140 |
|    | Persistence | | 2.00 | 93.1 | .197 | .129 |
| 36 | Early | 0.069 | 1.72 | 86.6 | .219 | .167 |
|    | Persistence | | 0.87 | 89.8 | .156 | .117 |
| 48 | Early | 0.030 | 1.35 | 94.0 | .124 | .083 |
|    | Persistence | | 1.98 | 91.8 | .052 | .047 |

Table 6.8. Same as Table 6.6 except for ceiling height, 1200 GMT cycle.

| Projection (h) | Type of Forecast | Rel. Freq. Cats. 1&2 combined | Bias Cats. 1&2 combined | Percent Correct | Skill Score | Threat Score |
|---|---|---|---|---|---|---|
| 12 | Early | 0.030 | 1.39 | 95.1 | .282 | .181 |
|  | Local |  | 0.74 | 97.5 | .494 | .340 |
|  | Persistence |  | 0.92 | 97.6 | .565 | .406 |
| 15 | Local | 0.035 | 0.73 | 96.3 | .362 | .235 |
|  | Persistence |  | 0.77 | 96.3 | .392 | .259 |
| 18 | Early | 0.047 | 1.50 | 92.1 | .295 | .201 |
|  | Persistence |  | 0.58 | 95.0 | .301 | .194 |
| 21 | Local | 0.057 | 0.77 | 92.9 | .282 | .189 |
|  | Persistence |  | 0.47 | 93.5 | .221 | .143 |
| 24 | Early | 0.068 | 1.53 | 88.6 | .280 | .205 |
|  | Persistence |  | 0.40 | 92.2 | .144 | .097 |
| 36 | Early | 0.030 | 1.41 | 94.1 | .159 | .104 |
|  | Persistence |  | 0.90 | 94.9 | .097 | .066 |
| 48 | Early | 0.069 | 1.57 | 87.0 | .204 | .157 |
|  | Persistence |  | 0.40 | 91.1 | .038 | .039 |

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Table 7.1.  Verification of the guidance max/min temperature forecasts for 87 stations, 0000 GMT cycle.

| Forecast Projection (h) | Type of Forecast | Mean Algebraic Error (°F) | Mean Absolute Error (°F) | Number (%) of Absolute Errors ≥10°F | Number of Cases |
|---|---|---|---|---|---|
| 24 (Max) | Early | 0.7 | 3.2 | 515 (3.3) | 15628 |
| 36 (Min) | Early | -1.3 | 4.2 | 1206 (7.7) | 15623 |
| 48 (Max) | Early | -0.2 | 4.3 | 1402 (9.0) | 15541 |
| 60 (Min) | Early | -2.2 | 5.4 | 2450 (15.8) | 15536 |

Table 7.4. Same as Table 7.1 except for 23 stations in the Central Region.

| Forecast Projection (h) | Type of Forecast | Mean Algebraic Error ($^{o}$F) | Mean Absolute Error ($^{o}$F) | Number (%) of Absolute Errors $\geq$10$^{o}$F | Number of Cases |
|---|---|---|---|---|---|
| 24 (Max) | Early | 1.0 | 3.4 | 149 (3.6) | 4140 |
| 36 (Min) | Early | -1.8 | 4.8 | 441 (10.7) | 4135 |
| 48 (Max) | Early | -0.2 | 4.5 | 418 (10.2) | 4117 |
| 60 (Min) | Early | -3.1 | 6.3 | 922 (22.4) | 4112 |

Table 7.5. Same as Table 7.1 except for 15 stations in the Western Region.

| Forecast Projection (h) | Type of Forecast | Mean Algebraic Error ($^{o}$F) | Mean Absolute Error ($^{o}$F) | Number (%) of Absolute Errors $\geq$10$^{o}$F | Number of Cases |
|---|---|---|---|---|---|
| 24 (Max) | Early | 0.8 | 3.0 | 84 (3.1) | 2700 |
| 36 (Min) | Early | -0.7 | 3.6 | 143 (5.3) | 2699 |
| 48 (Max) | Early | 0.7 | 4.0 | 201 (7.5) | 2685 |
| 60 (Min) | Early | -1.2 | 4.4 | 260 (9.7) | 2684 |

Table 7.7.  Same as Table 7.6 except for 25 stations in the Eastern Region.

| Forecast Projection (h) | Type of Forecast | Mean Algebraic Error ($^{o}F$) | Mean Absolute Error ($^{o}F$) | Number (%) of Absolute Errors $\geq 10^{o}F$ | Number of Cases |
|---|---|---|---|---|---|
| 24 (Min) | Early | -1.1 | 3.9 | 212 (4.8) | 4450 |
| 36 (Max) | Early | -0.7 | 3.8 | 272 (6.1) | 4450 |
| 48 (Min) | Early | -2.0 | 4.9 | 535 (12.0) | 4450 |
| 60 (Max) | Early | -1.6 | 4.7 | 490 (11.0) | 4450 |

Table 7.8.  Same as Table 7.6 except for 24 stations in the Southern Region.

| Forecast Projection (h) | Type of Forecast | Mean Algebraic Error ($^{o}F$) | Mean Absolute Error ($^{o}F$) | Number (%) of Absolute Errors $\geq 10^{o}F$ | Number of Cases |
|---|---|---|---|---|---|
| 24 (Min) | Early | -1.1 | 3.7 | 218 (5.1) | 4241 |
| 36 (Max) | Early | 0.2 | 4.1 | 315 (7.4) | 4240 |
| 48 (Min) | Early | -1.9 | 4.7 | 476 (11.2) | 4241 |
| 60 (Max) | Early | 0.1 | 4.9 | 557 (13.1) | 4240 |
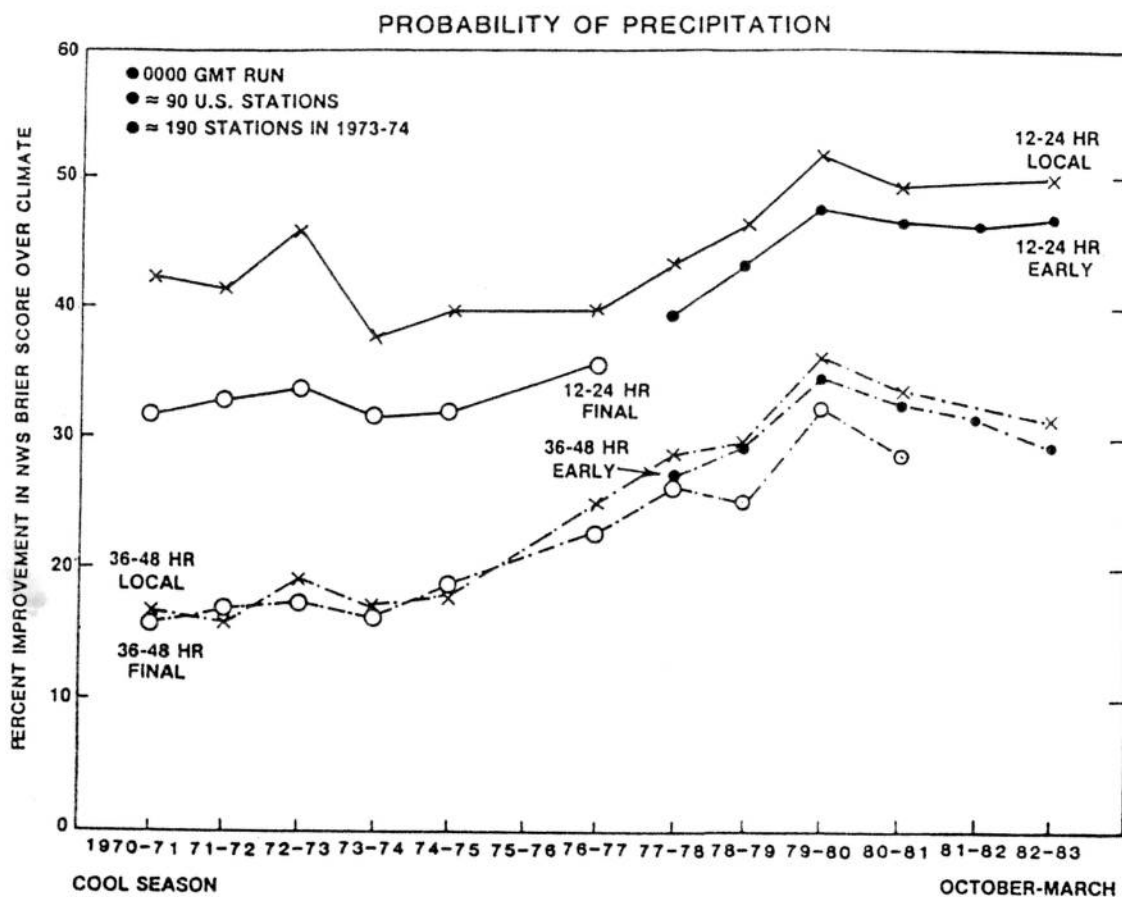
Figure 2.1. Percent improvement over climate in the Brier score of the local and the early and final guidance PoP forecasts. Results for 1975-76 (final and local) and 1981-82 (local) are unavailable because of missing data.
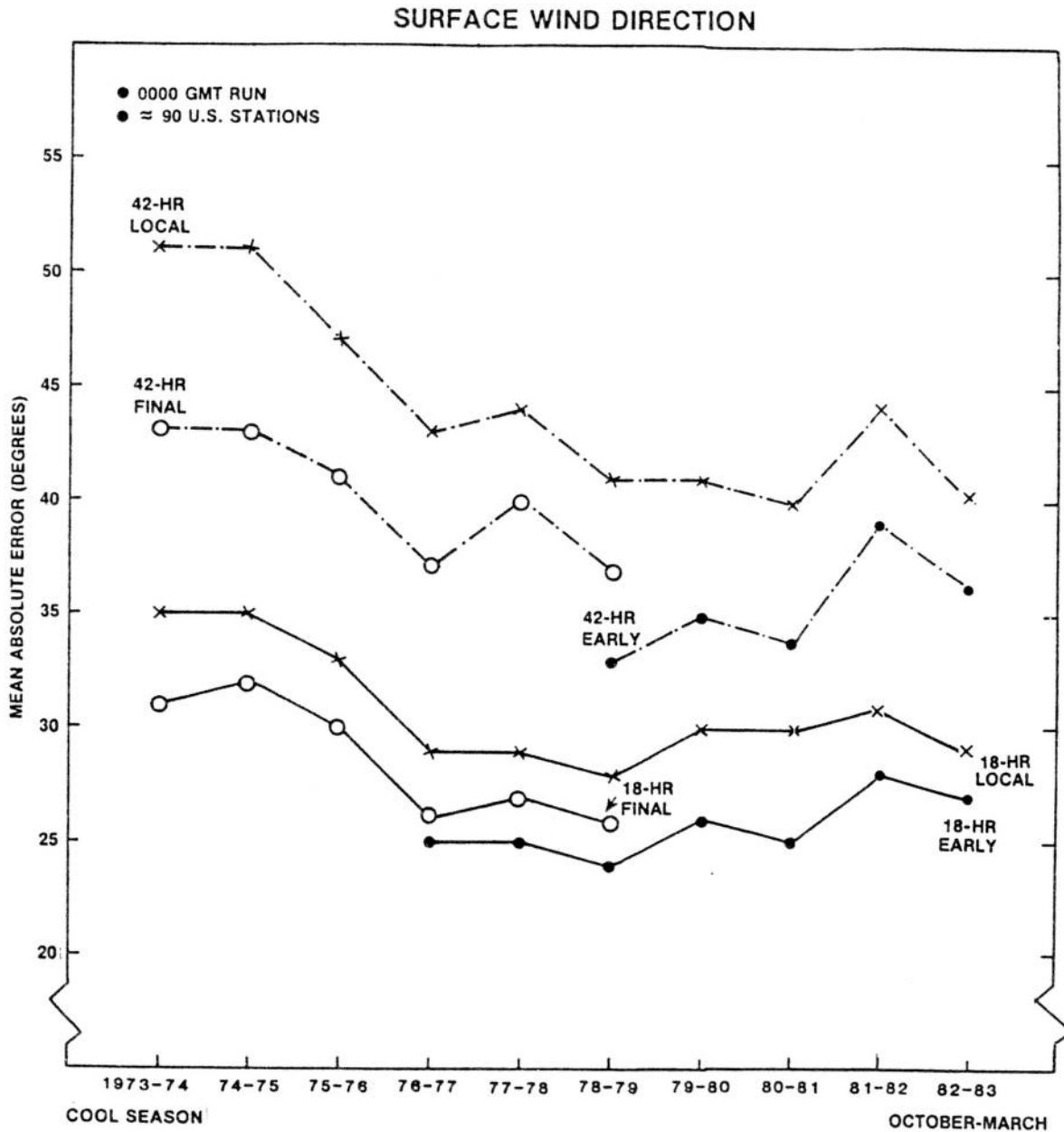
Figure 4.1. Mean absolute error for the local and the early and final guidance surface wind direction forecasts.

Figure 4.3. Skill score computed from five-category contingency tables for the local and the early and final guidance surface wind speed forecasts.

Figure 5.1. Percent correct for the local and the early and final guidance opaque sky cover forecasts.

Figure 5.3. Category 1 bias for the local and the early and final guidance opaque sky cover forecasts.
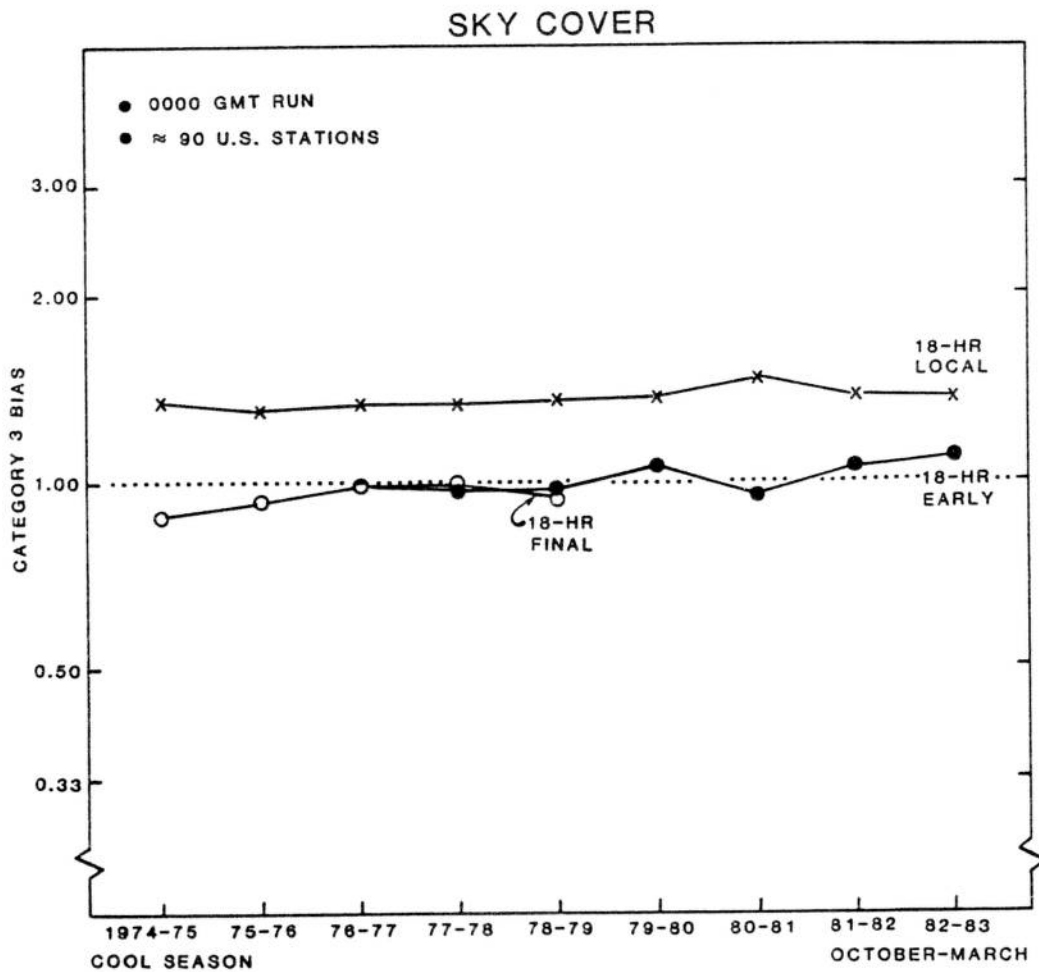
Figure 5.5. Same as Fig. 5.3 except for category 3 bias.

## CEILING



Figure 6.1. Skill score computed from two–category contingency tables for persistence, local, and guidance (early and final) ceiling height forecasts.
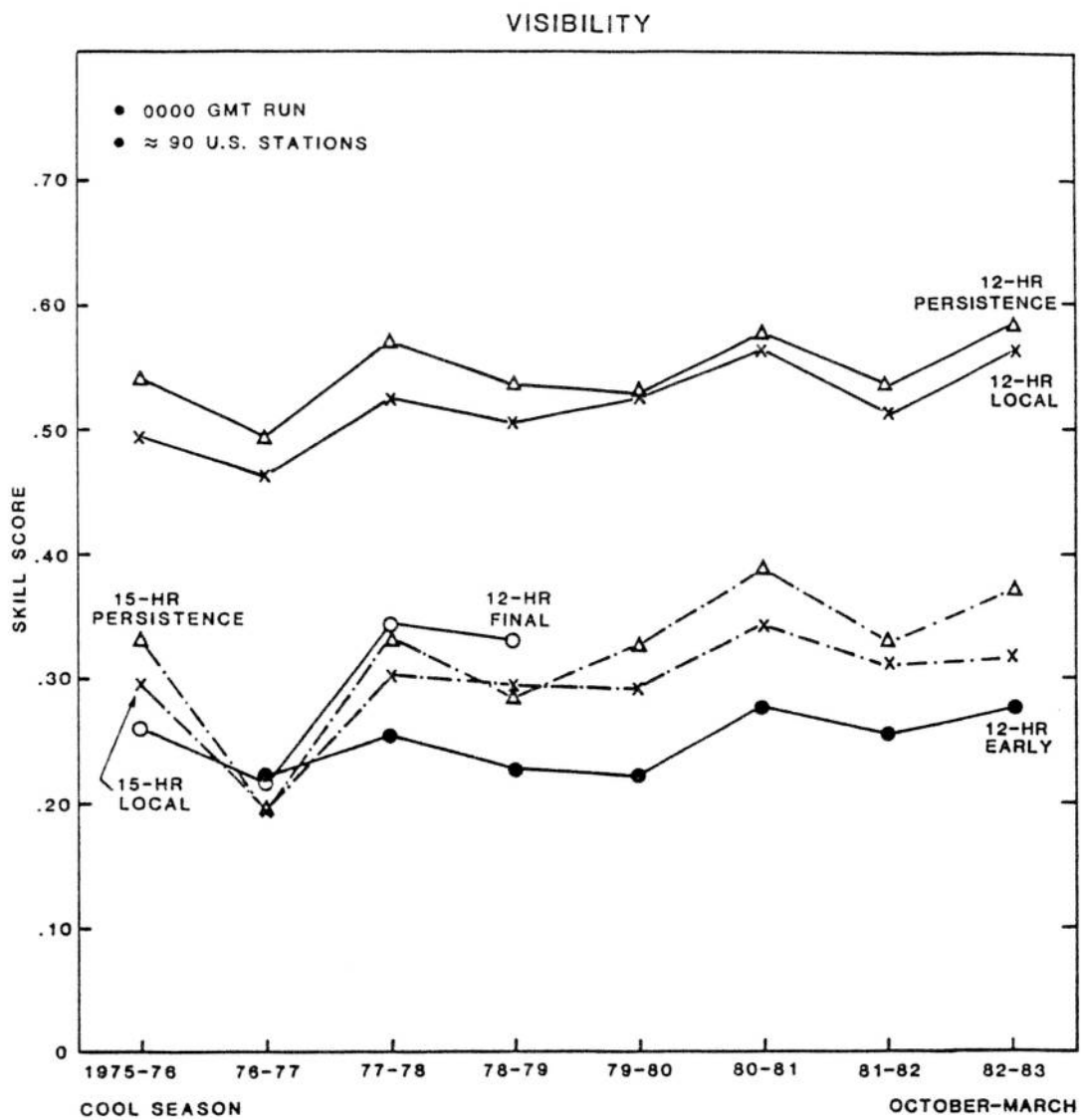
Figure 6.3. Same as Fig. 6.1 except for visibility.
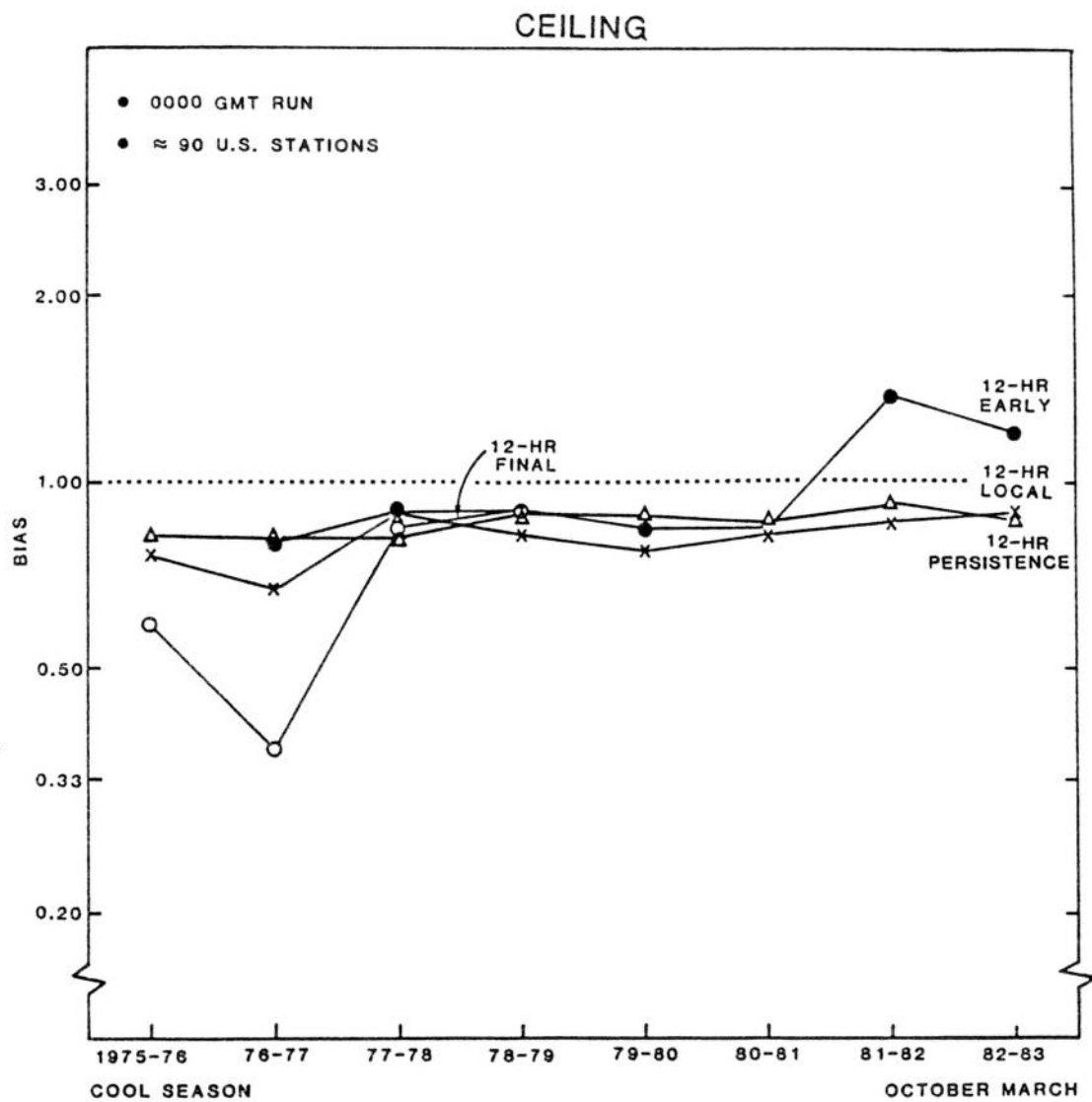
Figure 6.5. Bias for categories 1 and 2 combined for persistence, local, and guidance (early and final) ceiling height forecasts.
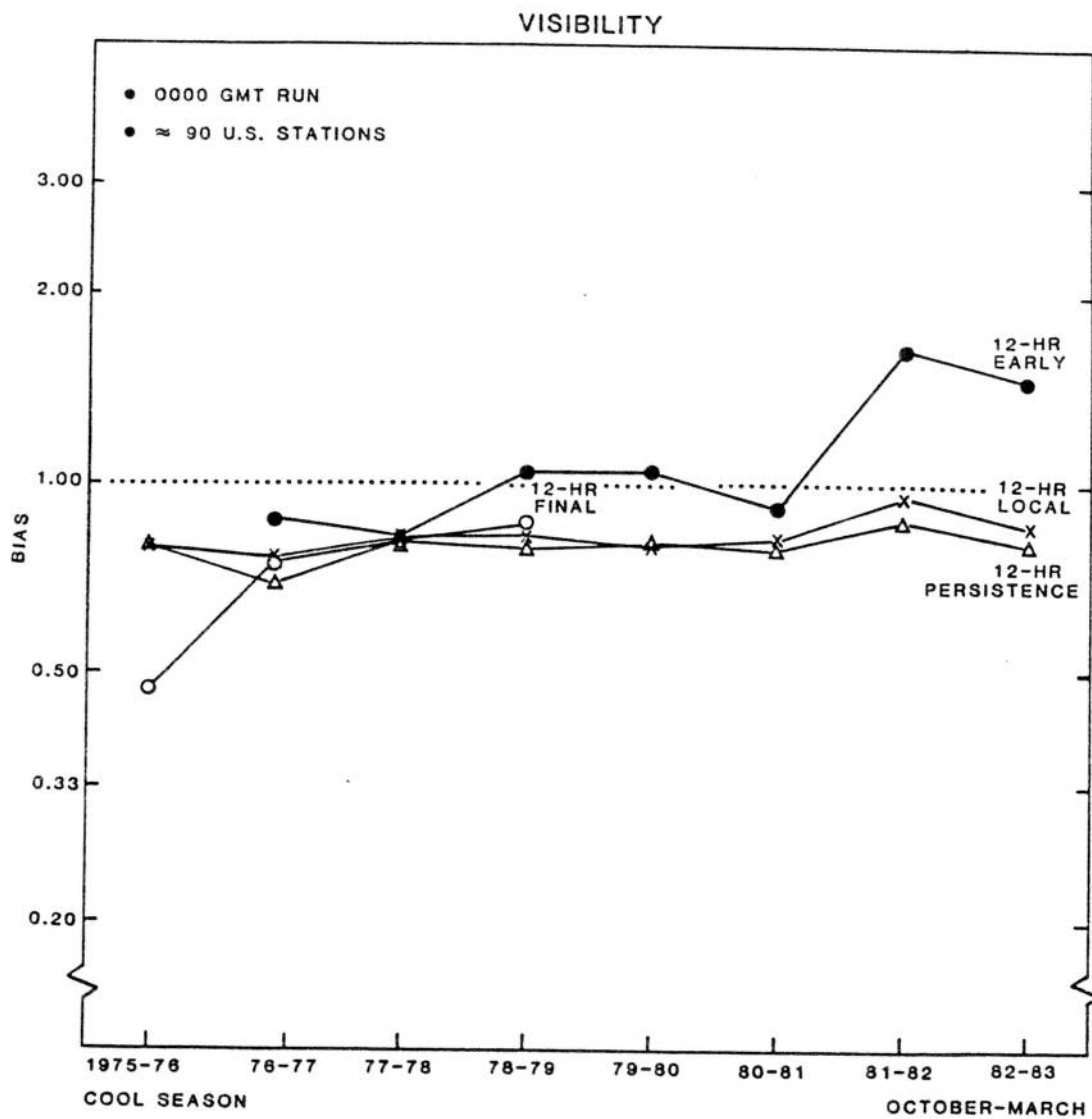
Figure 6.7.  Same as Fig. 6.5 except for visibility.

Figure 7.1. Mean absolute error for the local and the early and final guidance max temperature forecasts.